Relativistic Nuclear Collisions

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The Relativistic Nuclear Collisions Program (RNC) at LBNL conducts experiments which study the collisions of nuclei over a large energy range. At Bevalac energies nuclear matter is compressed sufficiently to study its equation of state. At the AGS at Brookhaven National Laboratory (BNL), these studies are extended to an energy range where the maximum pressure from the baryons is likely to occur. At the CERN-SPS the energy density of the system created in a collision of very heavy nuclei may be sufficient to produce a phase transition to a plasma of free quarks and gluons, whereas at the Relativistic Heavy Ion Collider (RHIC) the energy density is expected to be sufficiently high that production of the Quark-Gluon Plasma (QGP) should occur. At lower energies (Bevalac, AGS) one attempts to determine the equation of state of nuclear matter. However, the main goal of the current program is to excite the QCD ground state (vacuum) over a macroscopic volume in order to study its properties. The conceptual questions to be addressed are: What is the phase structure of QCD? Is there a phase transition to a QGP? Is there a chiral phase transition? Are the chiral and the QGP phase transition identical? What is the origin of the mass of the light hadrons? What are the properties of the chiral/QGP phase? Understanding those questions is of fundamental interest and is a central part of the U.S. Nuclear Science Long Range Plan.

RNC scientists presently are analyzing data from two large experiments, E895 at the AGS and NA49 at the CERN SPS. Both experiments produce a wealth of data and it is expected that the analysis will be completed this calendar year. The main focus of the high-energy heavy-ion research program at LBNL is the STAR experiment at RHIC, which will begin data-taking July this year.

STAR is a collider experiment at RHIC designed to study Au-Au collisions at a nucleon-nucleon center of mass energy of 200 GeV. Like in NA49, the goal is to simultaneously measure many hadronic signals that might indicate a phase change due to the increased number of degrees of freedom. To perform event-by-event analysis, almost all charged particles over two units of rapidity, centered at mid-rapidity will be measured and identified. Photons and neutral mesons will also be measured with this detector. At RHIC energies there is a high rate of hard processes. Hard-scattered partons are predicted to be sensitive to the medium through which they propagate. The process can be calculated in perturbative quantum chromodynamics. The study of high transverse momentum particles and jets as a function of energy and mass of the colliding system may also be an attractive experimental approach to identify the presence of quark-gluon matter. LBNL's Relativistic Nuclear Collisions Program is providing the focus for many STAR activities. Within the STAR organization, the RNC program is providing the project leadership, the engineering management and overall detector integration, as well as building a large fraction of the hardware. RNC has primary responsibility for the time projection chamber (TPC) and its electronics. This is the core and the raison d'Etre for STAR. RNC also has significant responsibilities within the software efforts in STAR. RNC physicists form the core of the software development team that is focused on tracking and particle identification in the TPC.

The RNC Program has broadened its physics base by starting the peripheral collisions physics program within STAR. For heavy ions at RHIC the luminosity for photon-photon interactions in peripheral collisions is very high so that an extensive program of meson spectroscopy becomes possible. At the same time Pomeron-Pomeron interactions and photon-Pomeron interactions, both of fundamental importance, can be investigated. In addition, we plan to participate in the SPIN physics program of STAR.

Analyzing the large amount of data accumulated with the STAR detector will be a formidable challenge. New concepts need to be developed and tested. The Grand Challenge Initiative is contributing to the data management design of the RHIC Computing Facility and we plan to implement a STAR data analysis center at LBNL in collaboration with NERSC.

Traditionally, TPCs have been read out with multiwire proportional chambers located over a surface of pads that pick up the induced signal from avalanches on the wires. This technology sets a practical limit on the two-track resolution and the position resolution that can be obtained with a TPC. The new Microstrip Gas Chamber (MSGC) devices can overcome this limit and allow TPCs to be operated in much higher track density environments with improved position resolution. It is the goal of our development to achieve position resolution and two-track separation comparable to those obtained with Si detectors so that these nearly massless micro-TPCs can be used for tracking close to the vertex. Such detectors would be an asset for heavy ion collider experiments such as STAR or ALICE (at the LHC).